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ANALYSIS OF THE RELEVANCE OF ASTROECOLOGICAL RESEARCH

Khomiak I.[1], **Onyschuk I.**[1], **Khomiak O.**[2]
[1]Zhytomyr Ivan Franko State University
Velyka Berdychivska str., 40, 10005, Zhytomyr
[2]Freiberg University of Mining and Technology
Fuchsmühlenweg, 9b, Freiberg, Germany
ecosystem_lab@ukr.net, oxanakhomiak@gmail.com

The article discusses the need to separate astroecology into a separate independent science. Such an accentuation will allow us to expand the scope of knowledge about life as a cosmic phenomenon and cleanse the modern general ecology from an exclusively earthly vision of life. The theories of general ecology must be filtered by the methods of astroecology. There is a mutual exchange of data between astroecology and terrestrial applied ecology, which enriches both sciences and increases the effectiveness of their projects. This, first of all, concerns the problems of restoration of disturbed ecosystems, ecological medicine, environmental safety, and agriculture. The article was written based on a review of publications in leading astrobiological journals and based on the experience of my own astroecological research. Astroecology should be to single out from astrobiology because it studies the relationships of biosystems with the environment as separate phenomena, and not only as separate characteristics of these biosystems. This will allow us to determine the main patterns of biota's relationship with the environment outside the Earth, which will give us new ecological theories and cleanse the general ecology of the earthly vision of life. The main functions of modern astroecology are to expand the sphere of knowledge, which will increase our chances of survival; creation of new ecological theories and critical analysis of old ones; uncovering mechanisms of adaptation to extraterrestrial environments that will facilitate our space expansion and prepare for future contact with extraterrestrial biota. General ecology must be built on theories filtered by astroecology because it encompasses the relationships with biota in space larger than one planet. Astroecology is enriched by the knowledge obtained in human-explored outer space and on our planet. When using the knowledge obtained on Earth, there is a two-way enrichment of classical terrestrial ecology and astroecology. Astroecology contributes to the progress of ecological science and improves the methods of applied ecology. This concerns, first of all, the problems of restoration of disturbed ecosystems, ecological medicine, environmental safety, and agriculture. *Key words:* astrobiology, ecological safety, space expansion.

Аналіз актуальності астроекологічних досліджень. Хом'як І.В., Онищук І.П., Хом'як О.І.
У статті обговорюється необхідність виділення астроекології в окрему самостійну науку. Такий акцент дозволить розширити сферу знань про життя, як космічне явище та очистити сучасну загальну екологію від виключно земного бачення життя. Теорії загальної екології повинні бути відфільтровані методами астроекології. Між астроекологією та земною прикладною екологією відбувається взаємний обмін даними, що збагачує обидві науки та підвищує ефективність їхніх проектів. Це, насамперед, стосується проблем відновлення порушених екосистем, екологічної медицини, екологічної безпеки, сільського господарства. Стаття написана на основі огляду публікацій у провідних астробіологічних журналах та на основі досвіду власних астроекологічних досліджень. З астробіології слід виокремити астроекологію, тому що вона вивчає зв'язки біосистем із середовищем як окремі явища, а не лише як окремі характеристики цих біосистем. Це дозволить визначити основні закономірності взаємовідносин біоти з навколишнім середовищем поза Землею, що дасть нам нові екологічні теорії та очистить загальну екологію від земного бачення життя. Основні функції сучасної астроекології – розширення сфери знань, що підвищить наші шанси на виживання; створення нових екологічних теорій і критичний аналіз старих; розкриття механізмів адаптації до позаземного середовища, які сприятимуть нашому космічному розширенню та підготують до майбутнього контакту з позаземною біотою. Загальна екологія повинна будуватися на теоріях, відфільтрованих астроекологією, оскільки вона охоплює відносини з біотою в просторі, більшому за одну планету. Астроекологія збагачується знаннями, отриманими в дослідженому людиною космосі та на нашій планеті. При використанні знань, отриманих на Землі, відбувається двостороннє збагачення класичної земної екології та астроекології. Астроекологія сприяє прогресу екологічної науки і вдосконалює методи прикладної екології. Це, насамперед, стосується проблем відновлення порушених екосистем, екологічної медицини, екологічної безпеки, сільського господарства. *Ключові слова:* астробіологія, екологічна безпека, космічна експансія.

Introduction

Statement of the problem. Ecology was born in the bosom of natural sciences at the height of the Scientific Revolution. Over time, theorists and practitioners of natural sciences have realized the importance of describing the relationships between environment and biota. Information about these connections accumulated more and more, and biology, overloaded with it, formed a separate section – ecology. However, other sections of biology continued to supplement their highly specialized sciences with ecology, where it was a multidisciplinary science. In certain branches of biology, the share of ecological research is so large that it is difficult to separate them from ecology, despite their own history and independent development. Astrobiology is one of the most tightly integrated sections of biology with ecology. Virtually every astrobiological study, hypothesis, or theoretical review is essentially ecological [9]. We get a question – should astroecology continue to develop as an independent science?

Research relevance. In our time, the volume of research into extraterrestrial space has reached its historical maximum. This is not only a consequence of their popularization. The results of extraterrestrial space research are growing, both qualitatively and quantitatively. For example, according to the "Government Space Defense" report, spending on the space sector was a record 103 billion dollars in 2022. This growth does not even come close to meeting the needs arising from the expansion of the "sphere of knowledge" and the growth of the "surface of the questions". For this reason, we have to be as efficient as possible.

The connection of the author's work with important scientific and practical tasks. At first glance, it seems that the wide using of ecological research methods and principles in astrobiology excludes the need to separate astroecology from it. It seems that astrobiology is already astroecology. It seems that astrobiology is already astroecology. To answer this question, we have to analyze the structure of astrobiology more deeply. We consider it more broadly than just exobiology or xenobiology. It will include both life on other natural space objects, as well as the influence of cosmic factors on biosystems and Earth's biota. The last two lines of research are indeed classically ecological, but the future study of extraterrestrial biota (exobiology or xenobiology) is much larger. In many publications devoted to this direction, ecological aspects are present but occupy only a small part of the entire array of research. For example, the search for biosignatures, and astrogeology that related to the search for traces of life in rocks of extraterrestrial origin, will be only partially ecological. Therefore, astroecology covers only a part of astrobiology. In some research, it completely dominates, and in others research only a small part of it is present.

Analysis of the latest research and publications. Astroecological research can be interdisciplinary and multidisciplinary in nature [11]. The focus of typical astroecology is not the objects of biota itself, but its relationships with the environment. So, when we look for the remains of life in a meteorite or an extraterrestrial rock, it is not an astroecological study in the classical sense [10]. It will be astroecology only when we are interested in the environmental conditions in the area of existence of this meteorite or rock, and how the found biota interacted with it or adapted to it.

Scientific novelty. For the first time, we made a detailed analysis of the journalistic activity of scientists in the field of astroecology.

Methodological or general scientific significance.

In certain branches of biology, the share of ecological research is so large that it is difficult to separate them from ecology, despite their own history and independent development. Astrobiology is one of the most tightly integrated sections of biology with ecology. Virtually every astrobiological study, hypothesis, or theoretical review is essentially ecological. At first glance, it seems that the wide using of ecological research methods and principles in astrobiology excludes the need to separate astroecology from it. It seems that astrobiology isalready astroecology. It seems that astrobiology is already astroecology. To answer this question, we have to analyze the structure of astrobiology more deeply. We consider it more broadly than just exobiology or xenobiology. It will include both life on other natural space objects, as well as the influence of cosmic factors on biosystems and Earth's biota. The last two lines of research are indeed classically ecological, but the future study of extraterrestrial biota (exobiology or xenobiology) is much larger.In many publications devoted to this direction, ecological aspects are present but occupy only a small part of the entire array of research. For example, the search for biosignatures, and astrogeology that related to the search for traces of life in rocks of extraterrestrial origin, will be only partially ecological. Therefore, astroecology covers only a part of astrobiology. In some research, it completely dominates, and in others research only a small part of it is present.

Purpose and objectives of the study. The purpose of the study is to determine the role and place of astroecology in modern science. Accordingly, the following tasks were set: 1) Analyze publications in the main astrobiological journals; 2) Determine the impact of astroecology on astrobiology and general ecology.

Materials and methods of research. Research materials are publications in leading astrobiological journals: "Astrobiology", "International Journal of Astrobiology" and "Life Sciences in Space Research". Common statistical methods were used for the analysis.

Research results. Take, for example, periodical peer-reviewed journals in which 50% or more of the publications are devoted to astrobiology (table 1). We can determine whether a publication belongs to astroecology by how the authors define the object of research. If the subject of research is the relationship of this biota with the environment, then such articles can be considered astroecological. If the subject of research is biota or the search for its traces and not its connections with the environment, then such a publication can be considered purely astrobiological. If it is not the subject of research but is mentioned in the results of the research or their discussion, then such a publication only contains elements of astroecological research. The distribution of publications into groups is based on the subjective opinion of the author. If a survey were conducted among a larger number of professional environmental researchers, the results below may change in one direction or another.

We have analyzed 26 scientific journals that contain astrobiological publications for the year 2022. From this list, 3 journals were selected, in which the share of classic astrobiological publications exceeded 50% (Table 1). These are "Astrobiology" (61.54%), "International Journal of Astrobiology" (56.76%), and "Life Sciences in Space Research" (56.6%). The rest of their publications were related to space but did not focus on studies of biota beyond Earth. These were studies of instruments for observing certain parameters of outer space, and questions of education, history, and philoso-

Table 1

The share of astroecological publications in the leading astrobiological journals

Name of the journal	Total number of publications	Astrobiological publications		Astroecological publications		Publications with elements of astroecology	
		Quantity (pcs.)	Share (%)	Quantity (pcs.)	Share (%)	Quantity (pcs.)	Share (%)
Astrobiology	13	8	61,54	2	15,38	2	15,38
International Journal of Astrobiology	37	21	56,76	8	21,62	4	10,81
Life Sciences in Space Research	53	30	56,60	11	20,75	4	7,55

phy. The share of identified astroecological publications, where the subject of research is the interaction of living organisms with the environment, ranged from 15.38% to 20.75% of the total number and from 25% to 38.09% of the number of astrobiological articles. Some researchers did not set themselves the main goal of studying the interrelationships of biota with organisms, but they mentioned this aspect in the articles. Such partly astroecological publications occupy from 7.55% to 15.38% of the total number and from 13.33% to 25% of the number of astrobiological publications. If we combine these categories together, their share will range from 28.3% to 32.43% of the total number and from 50% to 57.14% of the number of astrobiological publications.

Discussion. A large proportion of astrobiological research is related to terrestrial biota. First of all, we are talking about the study of extremophiles, the stability of Earth's ecosystems, global environmental changes and related extinctions, the relationship between man and the biosphere, life expectancy, and its preservation in extreme conditions. For example, our "Laboratory of Ecosystem Theory" studies the dynamics of the settlement of disturbed lands by plants. Our work is aimed at finding general patterns in the dynamics of the restoration of natural vegetation. This can be a theoretical basis for building algorithms for terraforming colonized planets. Such research of ours can be considered astroecological, because we study how species adapt to a certain lifeless environment and how they themselves change this environment, making it suitable for other groups of species.

The studies of extremophiles take into account their species diversity, genetics, morphological, biochemical, and biophysical responses to environmental conditions, and more [3]. Astroecological research in this direction is aimed at finding endurance limits for life in space [4]. At the same time, this region suffers the most from the earthly vision of life. What are extreme environmental conditions? We often consider them as such if they deviate significantly from the zone of optimum for humans or most living organisms on Earth. However, what is extreme for us or most species around us may be optimal for alien life [2]. Therefore, to define limits for life we need to form a universal definition of life in the universe [6].

Attempts to discover the causes of great extinctions keep turning our attention to extraterrestrial factors. For example, Yukio Isozaki [7] writes about this in his article "Paleozoic Extinctions in Cosmoclimatological Context: "Non-Bolide" Extraterrestrial Causes for Global Chilling". He emphasizes that recently paleobiologists and astrobiologists are increasingly returning to extraterrestrial causes of global extinctions. In his opinion, this is not a return to the old model associated with the fall of a large meteorite. It is a concept generated from new astrophysical discoveries that considers scenarios related to processes both within the solar system and beyond. It includes the direct and indirect influence of the Sun and other objects of the Solar System on the Earth's climate, echoes of supernova explosions, migration of dark matter, and, of course, classic falls of large meteorites. The direct impact was manifested through changes in the atmosphere or the amount of energy passing through it. Indirect influence was carried out through tectonic activity, which changed the physical and chemical properties of the atmosphere. We find similar ideas in other authors [1]. For example, the established 27.5 million-year cycle of catastrophic changes in the Earth's environment [13] is compared with the 32 ± 3 million-year cycle of vertical oscillations of the Solar System around the midplane of the Galaxy [14]. Some researchers believe that an increase in the flux of cosmic rays in the area of the plane of the Galaxy can lead to significant climatic changes [5].

Both for determining the extremes of conditions and for determining the threats of extinction, the central object of astrobiological research remains the human being [12]. For astrobiologists, man is a living creature equal in popularity to extremophile microorganisms. A large number of astrobiological publications are devoted to the effect of space flight directly on the human body or its simulation on animals. The absolute majority of these works are ecological. On the one hand, this is explained by the fact that medicine mostly deals with problems of human maladaptation to environmental conditions. For example, when a person loses the ability to fully function in certain environmental conditions. On the other hand, the causes of diseases can be both internal (hereditary-genetic, physiological) and external or environmental (biotic, abiotic and socio-psychologi-

cal) factors. The emergence of man beyond the surface of the Earth naturally puts the problem of adaptation in the first place. That is why a large part of astrobiological and space-medical research is astroecological. For example, in 2022, the journal "International Journal of Astrobiology" had 10% of such articles, and the journal "Astrobiology" – 6%. In this calculation, there were difficulties in determining in which category to assign the June 2022 special issue of the journal "Astrobiology". The journal "Life Sciences in Space Research" has the largest share of medical astroecological articles – 78%. There is a whole section "Health and biology in the space environment" and number 35 was completely devoted to the effect of radiation on the organism.

The ecologism of astrobiological research is manifested in the connection between the space environment and the biota of our planet, which covers the issues of life endurance limits, sudden catastrophic changes in the environment, the impact on organisms of being in an artificial environment outside the borders of the home planet, and the impact of space weather on the vitality. In addition, the ecological aspects of astrobiology are manifested in the questions of the origin of life on Earth and beyond. This is quite a popular topic in modern astrobiology [11]. For example, the journal "Astrobiology" published 25 such articles in 2022. On average, there were 2.1 publications per issue. Only one of the issues did not have any publication on the origin of life, and the maximum number of such articles reached 4 per issue. As a rule, these are 1 or 3 articles per issue (33.3% of issues). Most of these articles are closer to chemistry than to ecology. After all, they consider the connection of the abiotic process of the formation of prebiotics with the environment, and ecology examines the connection of supra-organismic biosystem levels with it. Ecology begins when we consider the formation of the first ecosystems or the likely vectors of evolution, rather than the prerequisites for the emergence of life.

Conclusions. Astroecology should be to single out from astrobiology because it studies the relationships of biosystems with the environment as separate phenomena, and not only as separate characteristics of these biosystems. This will allow us to determine the main patterns of biota's relationship with the environment outside the Earth, which will give us new ecological theories and cleanse the general ecology of the earthly vision of life.The main functions of modern astroecology are to expand the sphere of knowledge, which will increase our chances of survival; creation of new ecological theories and critical analysis of old ones; uncovering mechanisms of adaptation to extraterrestrial environments that will facilitate our space expansion and prepare for future contact with extraterrestrial biota. General ecology must be built on theories filtered by astroecology because it encompasses the relationships with biota in space larger than one planet. Astroecology is enriched by the knowledge obtained in human-explored outer space and on our planet. When using the knowledge obtained on Earth, there is a two-way enrichment of classical terrestrial ecology and astroecology. Astroecology contributes to the progress of ecological science and improves the methods of applied ecology. This concerns, first of all, the problems of restoration of disturbed ecosystems, ecological medicine, environmental safety, and agriculture.

References

1. Bostrom N., Ćirković M. Global catastrophic risks. *Oxford: Oxford university press*. 2011. P.554.
2. Carré L., Zaccai G., Delfosse X., Girard E., Franzetti B. Relevance of earth-bound extremophiles in the search for extraterrestrial life. *Astrobiology*. 2022. Volume 3. P. 322-367.
3. Cockell C. S., Harrison J. P., Stevens A. H. A low-diversity microbiota inhabits extreme terrestrial basaltic terrains and their fumaroles: implications for the exploration of Mars. *Astrobiology*. 2019. Volume 19. P.284-299.
4. Cockell C. S., Samuels T., Stevens A. H. Habitability is binary, but it is used by astrobiologists to encompass continuous ecological questions. *Astrobiology*. 2022. Volume 1. P. 7-13.
5. Gies D.R., Helsel J.W. Ice age epochs and the sun's path through the galaxy. *Astrophys*. 2005. № 626. P.844-848.
6. Hall L.S., Krausman P. R., Morrison, M. L. The habitat concept and a plea for standard terminology. *Wildlife Society Bulletin*. 1997. № 25. P.173-182.
7. Isozaki Y. Paleozoic Extinctions in cosmoclimatological context: «Non-Bolide» Extraterrestrial Causes for Global Chilling. *Paleontological Research*. 2022. № 1. P.14-24.
8. Khomiak Ivan, Khomiak Oksana. The influence of substrate particle size on the potential for spontaneous spread of biota across the landmass of rocky planets. Global science: prospects and innovations. Proceedings of the 7th International scientific and practical conference. Cognum Publishing House. Liverpool, United Kingdom. 2024. P. 314-319.
9. Khomiak Ivan, Khomiak Oksana. Using artificial intelligence for express-analysis of the biotic potential of alien habitat. Modern research in science and education. Proceedings of the 8th International scientific and practical conference. BoScience Publisher. Chicago, USA. 2024. P.203-208.
10. Khomiak Ivan, Vasylenko Olha. Using the rules of natural recovery of ecosystems for the process of revegetation and terra forming. Ekologiai racjonalne zarządzanie przyrodą: edukacja, nauka i praktyka: materiały z międzynarodowej konferencji naukowo-praktycznej. Łomża–Żytomierz, 15.11.2023r. 2023. S.199-203.
11. Malaterre C., Jeancolas C., Nghe P. The origin of life: What is the question? *Astrobiology*. 2022. P.851-862.
12. Onyschuk I.P., Khomiak I.V. The use of the complex action of environmental factors in the process of space colonization. *Ecological sciences*. 2022. № 3(42). P.107-110.
13. Rampino M. R., Caldeira K., Zhual Y. A pulse of the Earth: A 27.5-Myr underlying cycle in coordinated geological events over the last 260 Myr. *Geoscience Frontiers*. 2021. № 6. P.101-245.
14. Rampino M. R., Stothers R. B., Smoluchowski R., Bahcall J. N., Matthews, M. S., Geological periodicities and the Galaxy. *In the Galaxy and the Solar System*, University of Arizona press. 1986. P.241-259.